

***Atrichum androgynum* (Müll. Hal.) A. Jaeger in Portugal, Azores and Madeira, new to the European bryoflora**

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Abstract – *Atrichum androgynum*, is reported for the first time for Europe. The species was found in mainland Portugal, Madeira and Azores Archipelagos.

Bryopsida / Mosses / *Atrichum androgynum* / Portugal / Azores / Madeira / New Record

INTRODUCTION

The presence of an unusual species of *Atrichum* on the island of Madeira has been recognized since our first explorations of the local moss flora (1982 to 1996). It was identified as *Atrichum androgynum* (Müll. Hal.) A. Jaeger with some uncertainty, but the true identity of these collections has remained open.

During the taxonomic revision of the genus *Atrichum* P. Beauv. for the Iberian Flora, some collections from mainland Portugal were also identified as *A. androgynum*. Additionally the revision of some Azorean collections identified as *A. undulatum* (Hedw.) P. Beauv. proved to be identical to *A. androgynum*. As this species has not been previously reported for Europe or Macaronesia, we studied plants from different parts of its range and from different herbaria.

According to the worldwide revision of the genus (Nyholm, 1971), as well as by some recent floras (Merrill, 1994; Chuah-Petiot, 2003; Hyvönen, 2006) or regional treatments (Sloover, 1986; Lou & Koponen, 1986), *A. androgynum* is postulated to be related with *A. undulatum*, both being characterized by their fairly large size and able to develop more than one sporophyte from each perichaetium. However these characters are not exclusive for the *A. undulatum* complex.

According to the key in Nyholm (1971) it is evident that the separation of these two widespread species of *Atrichum* is based on their geographic distribution, with *A. undulatum* being a northern hemisphere taxon and *A. androgynum* a species of the southern hemisphere.

Considering the particular geographic position of the island of Madeira, the Azores archipelago and Portugal mainland as well as recent records of several

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bryophyte species of the southern hemisphere or from neotropical regions (Sérgio, 1984, 1989; Sim-Sim *et al.*, 2005; Stech *et al.*, 2007) as new in these areas, the presence of *Atrichum androgynum* would not be surprising. Lou & Koponen (1986), in their revision of Chinese *Atrichum*, pointed out that *A. undulatum* belongs to a problematic group of species in terms of the species delimitation, as well as nomenclature. The taxonomic problems refer to both European and North American taxa distinguished based on their ploidy level (Aberrahmann & Smith, 1982). However, these authors did not find any morphological differences between diverse cytotypes from the British Islands, nor based on their cultivation experiments. In majority of the floras *A. undulatum* is regarded as a northern hemisphere species widespread in Europe and common also in China and Japan (Noguchi, 1987). Two varieties are distinguished: var. *undulatum* and var. *gracilisetum* Besch.

Further examination of the recently collected samples from Macaronesia support our preliminary conclusions and suggest that the majority of the material from Madeira is better treated as *Atrichum androgynum*.

MATERIAL AND METHODS

The studied material was mainly composed of the specimens in LISU, but also included some representative herbarium specimens from S, H and BM as listed in the selected specimens (see selection on appendix 1).

Morphological characterization of the Portuguese plants of *Atrichum androgynum* as compared with *A. undulatum* was made on the basis of some recent floras or taxonomic revisions such as Nyholm (1971), Merrill (1994), Hyvönen (2006), Sloover (1986) and Lou & Koponen (1986).

The characters used to distinguish these two species are the gametophytic ones such as the lamellae of the ventral side of the costa, the pattern of the median leaf cells as well as the presence of more than one sporophyte per perichaetium (polysety). Figures 1-4 illustrate leaf cross-section in the median part and the pattern of median leaf cells. The laminal cells observed and outlined (Figs 5-8) are from the area beside the dorsal teeth and at an equal distance between the margin and the costa.

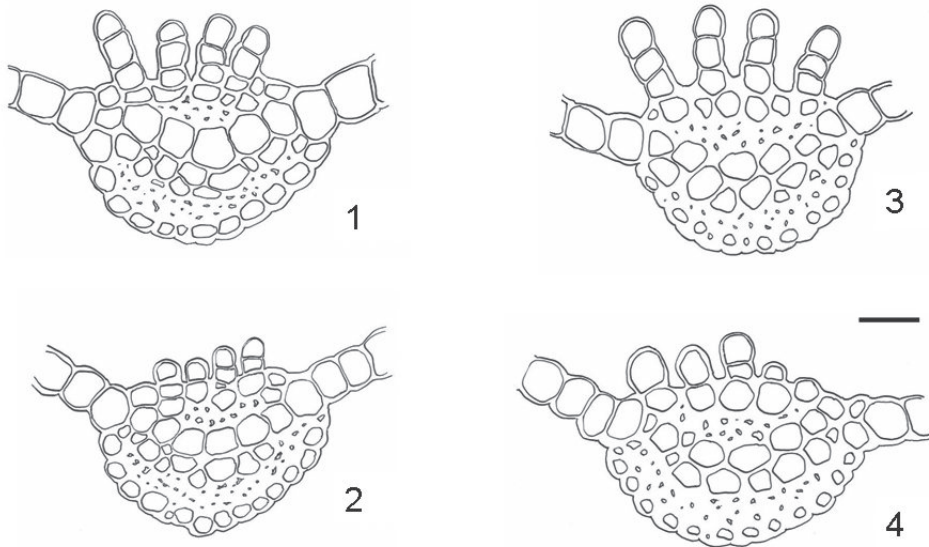
The present revision was made upon fertile plants in order to observe the number of sporophytes in each perichaetium.

RESULTS AND DISCUSSION

Morphology

We initiated our study by comparing specimens of *Atrichum undulatum* without polysety from diverse collections from different parts of Europe. The morphological characters of the gametophyte are dissimilar to plants with two or more sporophytes per perichaecium (*A. androgynum*).

From our observations, the following morphological characters resulted to be highly distinctive for these species. In *Atrichum undulatum* the ventral side of the costa bears 5-6 lamellae generally 3-6 cells high; in contrast, *A. androgynum* develops small and few ventral lamellae (3-4 very rare 5) formed by only 1-3 (very



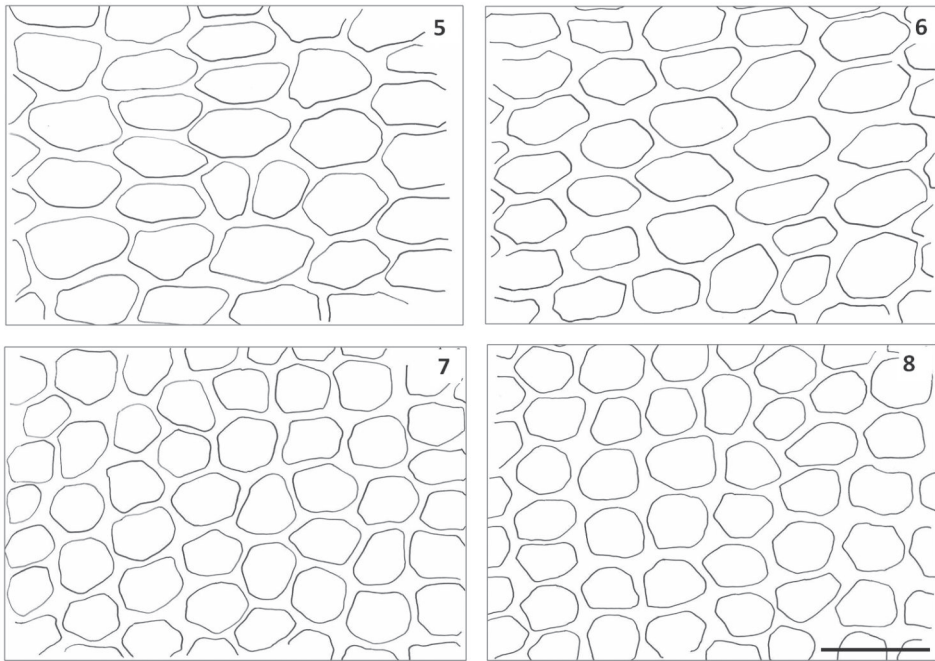
Figs 1-4. Transverse-section of nerve in central part of leaves of *Atrichum androgynum*. **1-2.** from Portugal, Cascata da Cabreia, C. Sérgio 11250 (LISU190612); **3-4.** from Madeira, Vereda do Posto da Encumeada, C. Sérgio & M. Nóbrega 3860 (LISU233123). Scale = 30 μ m.

rarely 4) rows of cells (Figs 1-4). In addition, other morphological characters can be considered. Although the pattern of median leaf cells seems to be consistently distinct in the two taxa, *A. undulatum* has median cells moderately thin-walled, more or less isodiametric, quadrangular to polygonal in shape, normally in regular vertical rows (Figs 7-8); in contrast, *A. androgynum* develops very incrassate cell walls which are transversely elongate, not or sporadically isodiametric, hexagonal to polygonal in shape, irregular or less evident vertical rows (Figs 5-6). This feature is clearly described by Merrill (1994) for Mexican plants of *A. androgynum*. The measures of lamina cells for both taxa are similar, about 20-35 μ m (larger size), becoming smaller towards the margins, with a fine cuticular striae at the base and median part.

The majority of the *Atrichum androgynum* collections from Madeira showed mature sporophytes, frequently with 2 or 3 or even more sporophytes. The setae were thick, dark red-brown in maturity. In addition all specimens from Azores and some from Portugal were fertile showing always polysety.

The presence of polysety is also used to distinguish var. *undulatum* from var. *gracilisetum* Besch., a common taxon in East Asia (Nyholm, 1971). However this author included it in *Atrichum flavisetum* Mitt. Currently, this species is characterized, among others features, by the yellow to brown setae (Brugués *et al.*, 2007), while the Macaronesian and Iberian plants of *A. androgynum* always have dark red setae.

The majority of the studied specimens were monoicous. The value of sexual condition as a diagnostic character in *Atrichum* has been considered and discussed by some authors (e.g. Biggs & Gibson, 2003). According to Brugués *et al.* (2007), *Atrichum undulatum* is an autoicous plant that can be functionally considered as a dioicous plant, since in some populations the male plants develop



Figs 5-6. Median leaf cells of *Atrichum androgynum*. **5.** from Portugal, Cascata da Cabreia, C. Sérgio 11250 (LISU190612); **6.** from Madeira L. Luís (LISU233161). Figs 7-8. Median leaf cells of *Atrichum undulatum*. **7.** from Azores, S. Miguel, Pico do Ferro, C. Sérgio 2548 (LISU233114); **8.** from España, Santander, Cameleño, C. Sérgio 9211 (LISU233118). Scale = 30 μ m.

during the first year, and the sporophytes follow in the same stem during the second year. Therefore further studies are needed to resolve this question in both *Atrichum* species.

The *Atrichum undulatum* spores seem to be variable according to Nyholm (1971), and for the Iberian plants they vary from 16 to 19 μ m in diameter (Brugués *et al.*, 2007). The spores of *A. androgynum* from the Azores, Madeira and mainland Portugal vary between 15 and 20 μ m.

Altogether, the two species have been considered morphologically close (Nyholm 1971). From this study, however, some diagnostic characters are confirmed to be useful to distinguish them. *Atrichum androgynum* always presents: 1) multiple sporophytes in the same perichaetium; 2) small number of lamellae (3-5), generally 1-3 cells high; 3) and an irregular pattern of the median leaf cells. The Macaronesian and mainland Portugal plants fit well the characters of this species, and in particular the fertile plants are easily recognized by the presence of 2-3 sporophytes per perichaetium.

Distribution and ecology

Atrichum androgynum is mainly considered to be a southern hemisphere plant. The worldwide distribution ranges from Africa, Australia to South America. So far, it has been recorded from New Zealand (Beever *et al.*, 1992) and

Australia (Hyvönen, 2006), in South America from Peru (Menzel, 1992) to Mexico and Colombia (Florschütz-de Waard & Florschütz, 1979), and Brazil (Molinari & Costa, 2001). In the Mexican flora the species was treated as *A. polycarpum* (Müll.Hal.) Mitt. (Merrill, 1994), but some authors (Bowers, 1974) have considered it as *A. androgynum*. This species has also been reported from numerous countries of Eastern Africa: Kenya Lesotho, Mauritius, Madagascar, Malawi, Mozambique, Reunion, South Africa, Swaziland and Zimbabwe (O'Shea, 2006), whence it has been reported with distinct names (Sloover, 1986).

The records documented here represent a considerable extension of the known distribution range of this species from the mountains of mainland Central Portugal towards Macaronesia. The occurrence of *Atrichum androgynum* in these two new areas probably represents a relict of the flora preceding the Pleistocene glaciations. Similar distribution patterns with tropical affinities are also shown by *Aneura pseudopinguis* (Schiffn.) Steph. (Sérgio & Garcia, 2009), *Dumortiera hirsuta* (Sw.) Nees, *Lejeunea eckloniana* Lindenb. and *Asterella africana* (Mont.) A.Evans. It can be noted that *Amphidium tortuosum* (Hornsch.) Cufod. (= *Amphidium curvipes* (Müll. Hal.) Broth.), formerly considered a Macaronesian endemic, is an austral taxon dispersed from South America, Central Africa to Papua New Guinea (Norris & Koponen, 1999) and also present in Madeira (Sérgio *et al.*, 2006).

Although *Atrichum undulatum* has been referred to the Canaries in two islands, La Palma and Tenerife (González-Mancebo *et al.*, 2008), we could not study specimens of these Islands and thus their identity needs to be confirmed in the future.

In the island of Madeira *Atrichum androgynum* has mostly been collected in the natural, laurel dominated forests (*Laurisilva*) at the altitudes of 400-1200 m. The accompanying bryophyte flora is diverse and includes some Macaronesian endemics. The species are typical of wet slopes such as *Anthoceros caucasicus* Steph., *Asterella africana* (Mont. in Barker-Webb *et Berth.*) Evans, *Dumortiera hirsuta*, *Jubula hutchinsiae* (Hook.) Dumort., *Lejeunea eckloniana*, *L. flava* (Sw.) Nees, *L. lamacerina* (Steph.) Schiffn., *L. patens* Lindb., *Metzgeria leptoneura* Spruce, *Plagiochila bifaria* (Sw.) Lindenb., *P. porelloides* (Torrey ex Nees) Lindenb., *P. punctata* (Taylor) Taylor, *Radula holtii* Spruce, *Saccogyna viticulosa* (L.) Dumort., *Tylimanthus madeirensis* Grolle *et* H. Perss., *Amphidium tortuosum*, *Andoa berthelotiana* (Mont.) Ochyra., *Campylopus flexuosus* (Hedw.) Brid., *Cyclodictyon laetevirens* (Hook. *et* Tayl.) Mitt., *Epipterygium tozeri* (Grev.) Lindb., *Fissidens luisieri* P. de la Varde., *Hookeria lucens* (Hedw.) Sm. *Philonotis rigida* Brid., *Plagiomnium rostratum* (Schrad.) T. Kop.

Atrichum androgynum can also be found in Madeira heath forests above 1000 m on wet substrates, in association with *Anthoceros agrestis* Paton, *Chiloscyphus polyanthos* (L.) Corda, *Pellia epiphylla* (L.) Corda, *Plagiochila bifaria*, *Saccogyna viticulosa*, *Scapania undulata* (L.) Dumort., *Southbya tophacea* (Spruce) Spruce, *Polytrichum commune* Hedw., *Racomitrium aciculare* (Hedw.) Brid., *Sphagnum auriculatum* Schimp. and *Thamnobryum alopecurum* (Hedw.) Gangulee.

In the Azores it was found in small areas at 690m, representing fragments of the native natural vegetation composed mainly by *Juniperus brevifolia* (Seub.) Antoine, and *Erica azorica* Hochst. ex Seub. It was growing together with *Heteroscyphus denticulatus* (Mitt.) Schiffn., *Saccogyna viticulosa* and *Tetrastichium fontanum* (Mitt.) Cardot.

The mainland Portuguese localities are in disturbed areas at 400-1100 m in the NE part of the country with a typically oceanic climate. Accompanying

bryophyte species in the Portuguese mainland include some oceanic/macaronesian bryophytes such as *Saccogyna viticulosa* and *Philonotis rigida* Brid. *Atrichum androgynum* might have been overlooked in the past and thus might be more frequent in the oceanic forest, Atlantic coastal mountains or deciduous woodlands, in shaded moist banks frequently in association with *Saccogyna viticulosa*.

However, it is obvious that further studies are required to elucidate the relationships between the northern hemisphere populations of *Atrichum undulatum* complex, the *A. androgynum* populations reported here, and those from the southern hemisphere. Detailed phylogenetic studies with targeted sampling from different parts of the range and use of the sequence level data are clearly needed in order to clarify the taxonomy of this species complex.

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Appendix 1. Selected studied material

Atrichum androgynum (Müll. Hal.) A. Jaeger

Azores: S. Jorge, Norte Grande, 690 m, MH087789, 22.06.1999, C. Sérgio 11709 (LISU 225092).

Portugal: Beira Litoral: Aveiro, estrada de Serabigões, NF6538, 132 m, 22.01.2003, C. Sérgio 13087 (LISU204327); Sever do Vouga, Cascata da Cabreira, Rio Mau, 400 m, 29TNF51, 12.06.1999, C. Sérgio 11250 (LISU190612); Minho: Entre Monção e Melgaço, Ponte de Mouro, 29TNG5850, 18.03.1981, C. Sérgio 3061 (LISU233115); Trás-os-Montes e Alto Douro: Serra do Alvão, Ermelo, S. João, Ribeira de Fervença, 450-500 m, NF9580, 22.04.1998, C. Sérgio et al. (LISU213524).

Madeira: Chã de Louros, Posto Florestal da Encumeada de S. Vicente, 800 m, CB1126, 05.11.1982, C. Sérgio & M. Nóbrega 3791 (LISU233122); Cruzinha do Faial, Cabeço da Fajã dos Vinháticos, 700-800 m, CB2125, 10.16.1991, C. Sérgio et al. 7668 (LISU233133); Faldas do Pico Jorge, Ribeira Bonito, 200-400 m, CB2030, 04.12.1988, C. Sérgio & M. Nóbrega 6184 (LISU233134); Levada do Caramujo para a Ribeira do Inferno de S. Vicente, 1000-1100 m, CB0727, 11.10.1990, C. Sérgio et al. 7360 (LISU233131); Portela, caminho para Machico, 500-600 m, CB2824, 09.10.1990, C. Sérgio et al. 7265 (LISU233129); Vão do Fanal, descida para o Fanal, antes da casa da Guarda, 1200m, 11.10.1990, CB0030, C. Sérgio et al. 7401 (LISU233132); Vereda da Levada de Ribeiro Frio para Balcões, 870-900 m, CB2323, C. Sérgio et al. 7219, 7222 (LISU233126, LISU233127); Vereda do Posto da Encumeada para a Ribeira Grande de S. Vicente, 600 m, CB1126, 05.11.1982, C. Sérgio & M. Nóbrega 3860 (LISU233123); Ribeira da Cruz, Paúl da Serra, 1040 m, BB9432, 27.06.2005, L. Luís & C. Cafofo (LISU 233161); Ribeira da Ponta do Sol, Bica da Cana, 150 m, BB0625, 15.06.2005, L. Luís & C. Cafofo (LISU 233162); Levada do Norte, entrada do 3º túnel, 1000 m, CB0727, 05.08.2002, M. Sim-Sim et al. (LISU 233164); Vereda do Velho ou do Plano (acima da Levada do Norte), 1100 m, CB0727, 11.06.2004, C. Lobo & L. Luís (LISU233165); Vereda do Velho, 1150 m, CB0628, C. Lobo & L. Luís (LISU 233166).

Colombia: Charala, Corregimiento Virolin, El Volcan, 1725 m, 20.10.1989, R.R. Ireland (H3006904).

South Africa: Transvaal, Tzaneen, Woodbush Forest reserve, 1800 m, 12.01.1986, W. Buck 13391 (H3006897); King Williams Town, Amatola, 26.01.1961, B.J. Chohnoky (S).

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Azores: Ilha do Faial, Caldeira do Faial, 800 m, LH57, 21.06.1982, *C. Sérgio* 4307 (LISU233111); S. Miguel, Lagoa do Fogo, no Miradouro, PG38, 25.05.1980, *C. Sérgio* 2711 (LISU233112); S. Miguel, Pico do Ferro, a 2 km da Lagoa das Furnas, PG48, 24.05.1980, *C. Sérgio* 2548 (LISU233114); S. Miguel, Vista do Rei, Lagoa das Sete Cidades, PG18, 25.05.1980, *C. Sérgio* 2650 (LISU233113).

Madeira: Fanal de Baixo, Ribeira Funda, 800 m, CB0032, 28.06.1988, *C. Sérgio* & *M. Nóbrega* 6388 (LISU233124); Ribeira dos Marinheiros, zona acima das Casas (povoação), BB9430, 920 m, 28.06.2005, *L. Luís* (LISU233163).

Portugal: Baixo Alentejo: Herdade da Ribeira Abaixo, 160-220 m, 29SNC3718, 1998, *C. Sérgio* & *C. Garcia* (LISU171294); Beira Baixa, Serra da Malcata, próximo da ponte para Quadrazais, 815 m, 29TPE6964, 22.11.2005, *M. Sim-Sim*, *C. Garcia* (LISU196173); Beira Litoral: Coimbra, Côja, Benfeita, Fraga da Pena, 400-700 m, 29TNE9052, 07.05.1985, *C. Sérgio* 5483 (LISU201694); Condeixa, Conimbriga, 200 m, 29TNE4338, 1984, *C. Sérgio et al.* (LISU201691); Estremadura: Porto de Mós, Figueiredo, 200m, 29SND1480, 1982, *M. Brugués et al.* (LISU201693); Minho: Corno do Bico, Travassos, próximo de Coutos, 640-650 m, 29TNG4137, 09.04.2001, *C. Garcia et al.* (LISU197763); Trás-os-Montes e Alto Douro: entre Pitões e Paradela, Carvalhal de Sezelhe, 1100 m, 29TNG9129, 21.06.1984, *C. Sérgio* 5292 (LISU153979).

Belgium: Malmedy, pr. Eau Rouge, vertente sul de Hautes Fagnes, 03.11.1980, *C. Sérgio* 2880 (LISU233110).

Spain: Cantabria, Santander, Camaleño, Invernales de Mato, Las Ilces, 1000 m, UN5574, 08.06.1994, *C. Sérgio* 9211 (LISU233118); "Pirineus", s/loc., 08.1933, *R. Palhinha* (LISU5636).